MECH 575
Introduction to Hydrodynamic Stability
Spring 2017

Introduction to linear and nonlinear instabilities that cause transition from laminar to turbulent flows in thermo-fluid systems. The physics of various canonical instability mechanisms and the mathematical and numerical frameworks common in stability analysis are discussed. Examples from industrial, geophysical, environmental, and astrophysical flows are presented.

Instructor:

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Office Hours

Wednesdays 11am-12pm or by appointment

Class:

Hours: TR 9:25am-10:40am
Room: MECH 128

Pre-requisites:

Undergraduate fluid mechanics and applied math (especially linear algebra, differential equations, and Fourier analysis). Familiarity with basic programming in MATLAB (or another programming language) and elementary concepts of numerical analysis.

Grading:

Homework (15%): Two problem sets consisting of analytical and numerical problems
Midterm (35%): Take-home exam
Presentation (50%): A critical evaluation of three published papers on a stability problem

Textbook:

- P. G. Drazin, Introduction to hydrodynamic stability, Cambridge University Press

Other suggested resources:

- P. K. Kundu and I. M. Cohen, Fluid mechanics, Academic Press
- P. G. Drazin and W. H. Reid, Hydrodynamic stability, Cambridge University Press
- P. J. Schmid and D. S. Henningson, Stability and transition in shear flows, Springer
- W. O. Criminale, T. L. Jackson, R. D. Joslin, Theory and computation of hydrodynamic stability, Cambridge University Press

All books are on reserve at Fondren Library (Kundu's book is also available online)

Notice:

Any student with a disability requiring accommodation in this course is encouraged to contact the instructor as soon as possible. Also these students should contact Disability Support Services in the Ley Student Center.

Honor Code:

Students must abide by the Honor Code on the take-home exam and the homework assignments. You can use the class notes, your graded homework assignments, and the textbook and suggested books for the take-home exam. You cannot use any other resource (e.g. journal or conference papers, other books, internet etc.) for the take-home exam. Collaboration/discussion is not allowed on the take-home exam. You can discuss the homework problems with your classmates and consult any book when working on the homework problems; however, the submitted work must be entirely yours and you should not copy solutions/results from others.

Outline:

Note: Sections/Chapters are from the version of Kundu that is available online

Lecture	Topic	Optional reading
Lecture 1: Jan. 10	Fundamental concept of fluid (in)stability; some examples and applications	Kundu: 4.1-4.6
Lecture 2: Jan. 12	Equations of motion for fluid flows; Navier-Stokes and Boussinesq equations; Some analytical solutions	Kundu: 8.1-8.2 & pages 135-137
Lecture 3: Jan. 17	Equations for perturbations; non-dimensionalization; example: Rayleigh-Benard problem	Kundu: 4.11 & 11.4
Lecture 4: Jan. 19	Continuing Lecture 3; Linearization; example: Couette problem	Drazin: 6.1-6.2
Lecture 5: Jan. 24	More on Couette problem; Modal analysis	Drazin: 8.1 Kundu: Chapter 2 (review of math)
Lecture 6: Jan. 26	More on linearization and modal analysis *End of the review period*	Kundu: Chapter 2 (review of math) Kundu: 4.11
Lecture 7: Jan. 31	Rayleigh-Benard instability	Kundu: 11.4
Lecture 8: Feb. 2	Rayleigh-Benard instability Homework #1 posted	Drazin: 6.1-6.3
Lecture 9: Feb. 7	Centrifugal instability (Taylor-Couette flow)	Kundu: 11.6
Feb. 9	*No class (recess)*	
Lecture 10: Feb. 14	Centrifugal instability (Taylor-Couette flow)	Drazin: 7.1-7.3
Lecture 11: Feb. 16	Numerical stability analysis Deadline: Homework #1	
Lecture 12: Feb. 21	Kelvin-Helmholtz instability	Kundu 6.1-6.2 Kundu 11.3
Lecture 13: Feb. 23	Kelvin-Helmholtz instability	Drazin: 3.1-3.8
Lecture 14: Feb. 28	Kelvin-Helmholtz instability	Kundu 11.7-11.10
Lecture 15: March 2	Stability of parallel flows Homework #2 posted	Drazin 8.1-8.3
Lecture 16: March 7	Stability of parallel flows	Drazin 8.5-8.7
Lecture 17: March 9	Stability of parallel flows	Prepare for midterm
March 14 March 16	*No class (spring break)*	Prepare for midterm

Lecture 18: March 21	Review Take-home midterm posted	Prepare for midterm
Lecture 19: March 23	Stability of boundary layers Deadline: Take-home midterm	Kundu 11.11
Lecture 20: March 28	Zombie vortex instability	Drazin 8.10
March 30	*No Class*	
Lecture 21: April 4	Crow instability and baroclinic instability *End of the modal linear stability analysis*	
Lecture 22: April 6	Non-normal growth and non-modal analysis *End of linear stability analysis* Deadline: Homework #2 Deadline: one-page summary of the presentation	Trefethen's notes
Lecture 23: April 11	Nonlinear stability and Transition to chaos	Kundu 11.2-11.13
Lecture 24: April 13	Presentations	
Lecture 25: April 18	Presentations	
Lecture 26: April 20	Presentations	